DESCRIPTION

DISPLAY DEVICE

TECHNICAL FIELD

The present invention relates to a display device and more particularly relates to a structure for mounting a display panel.

BACKGROUND ART

Recently, various types of flat panel displays have been used as replacements for CRT display devices. Among other things, LCDs have been used extensively as displays for cell phones, PDAs and other mobile electronic devices by taking advantages of its reduced thickness, light weight and low power consumption.

Particularly when an LCD is used in one of those mobile applications, the thickness and weight of the display device should be further reduced. To fill that need, the thickness of a glass substrate, which accounts for most of the thickness

and weight of the display device, has been reduced in one way or another. However, the glass substrate with such a reduced thickness breaks very easily. Thus, people have been researching on replacing a glass substrate with a plastic substrate.

Even when its thickness is reduced, a plastic substrate does not break so easily. Thus, a plastic substrate realizes a flexible display device such as a sheet display (or a film display) or a wearable display.

In general, a plastic material has a higher degree of elasticity (i.e., greater fracture ductility), and is much less breakable, than glass. However, when it comes to the substrate material of a display device, a plastic may not be used by itself. For example, if an LCD to make is a simple matrix type, the plastic substrate will be acceptable because just a single layer of an inorganic material needs to be deposited thereon as picture element electrodes. Meanwhile, if an active-matrix LCD needs to be fabricated, then a number of inorganic films should be deposited at various temperatures

and then patterned with high precision. That is why the thermal expansivity of the substrate must be reduced in that case.

Thus, a substrate, of which the thermal expansivity is reduced by compounding a plastic with a glass filler or fiber (which will be referred to herein as a "composite plastic substrate") while maintaining transparency, has been developed. Such a composite plastic substrate has intermediate physical properties between glass and plastic. Accordingly, in a situation where strong stress is produced locally (e.g., when the surface of the substrate is strongly hit by the edge of a hard object), the composite plastic substrate may sometimes break. However, it was confirmed that except under those severe conditions, the composite plastic substrate had too high resistance to external force or shock to be breakable under an ordinary external force or shock that would produce under normal operating conditions of the display device.

Nevertheless, if an LCD with such a composite plastic

substrate were used as a mobile display, the LCD might be damaged even when the external force or shock applied would cause no problem on the substrate by itself. Also, it is expected that when used as a flexible display, the LCD will be subject to greater external force as compared with conventional operating conditions.

Thus, the present inventors carried out experiments to find why the composite plastic substrate was broken when assembled into an LCD. As a result, we discovered that the breakability of the composite plastic substrate was greatly affected by the structure for mounting an LCD panel.

It is already known that a glass substrate also has its breakability affected by its mount structure. Thus, various mount structures for preventing the breakage have been proposed.

For example, Japanese Utility-Model Application Laid-Open Publication No. 61-124016 proposes a structure where a resin reinforcing plate, of which the thickness is at least 0.4 time as large as the overall thickness of an LCD panel, is

bonded onto the entire single side of the LCD panel with either an adhesive or a double coated tape. This structure is not preferable because the reinforcing plate is provided to cover the entire surface of the LCD panel, including its display area, and decreases the optical efficiency. Also, if the reinforcing plate had too high rigidity, then the flexibility of the LCD panel would be affected. However, a reinforcing plate with too low rigidity could not prevent the breakage effectively.

In some structures, an LCD panel is supported on a frame that has an opening corresponding in shape to the display area of the LCD panel. For example, Japanese Patent Application Laid-Open Publication No. 5-165013 discloses a structure in which an LCD panel is fixed onto an outer casing with an adhesive layer made of an elastic material. On the other hand, Japanese Patent Application Laid-Open Publication No. 11-153781 discloses a structure in which the outer edges of an LCD panel is inserted and fixed into a Y-fixing member made of an elastic material and in which the fixing member is further secured to a frame.

However, the present inventors discovered and confirmed via experiments that with the structures disclosed in Japanese Patent Application Laid-Open Publications Nos. 5-165013 and 11-153781, the breakage of the glass substrate could be minimized effectively but that of the composite plastic substrate could not.

More particularly, the present inventors discovered as a result of those experiments that in most of LCD panels with the composite plastic substrate, the breakage happened where the LCD panel was directly in contact with its frame (which will be referred to herein as a "supporting portion"), no matter whether the outer periphery of the LCD panel was fixed onto the frame on the viewer's side thereof or its opposite side. The reason is believed to be as follows.

As compared with a plastic substrate, a glass substrate has smaller fracture strain and breaks easily even under relatively small external force or shock. Thus, by making an elastic member cushion the external force or shock and reduce the strain produced in the glass substrate, the breakage of

the glass substrate can be avoided effectively. On the other hand, in the composite plastic substrate with relatively large fracture strain, it would be difficult for even an elastic member to absorb the external force or shock causing so great a strain as to break the composite plastic substrate.

Hereinafter, it will be described with reference to FIGS. **5(a)** through **5(c)** exactly how damage is done on an LCD panel **1** including a composite plastic substrate in an arrangement in which the LCD panel **1** is fixed onto an elastic frame **12**. It should be noted that the elastic frame **12** schematically illustrates a frame with an adhesive layer made of an elastic material as disclosed in Japanese Patent Application Laid-Open Publication No. 5-165013 and does not have to be a single member.

As shown in FIG. **5(a)**, while no external force is being applied, the LCD panel **1** including the composite plastic substrate is fixed on the elastic frame **12**.

However, when external force is applied to the LCD panel

1 as pointed by the arrow in FIG. 5(b), the LCD panel 1 deforms. Since the composite plastic substrate has a relatively great fracture strain, no breakage will occur even if the composite plastic substrate has deformed to a greater degree than a glass substrate. A flexible display is realized by taking advantage of this feature.

In this case, as the LCD panel 1 deforms, the elastic frame 12 also deforms, thereby preventing excessive stress from being concentrated on the LCD panel 1 at the edge of the elastic frame 12.

However, as the degree of deformation of the LCD panel 1 increases, it becomes more and more difficult for the elastic frame 12 to deform correspondingly. As a result, excessive stress will soon be concentrated on the LCD panel 1 at the edge of the elastic frame 12 to break the panel 1 as shown in FIG. 5(c).

It should be noted that the frequency of occurrence of this breakage does not depend so heavily on whether the LCD panel 1 is adhered to the supporting portion of the frame 12.

As described above, the arrangements disclosed in Japanese Patent Application Laid-Open Publications Nos. 5-165013 and 11-153781 in which the elastic material (or soft material) is interposed between the LCD panel and the frame cannot effectively prevent a relatively greatly deformable LCD panel from being broken.

Meanwhile, Japanese Patent Application Laid-Open Publication No. 2000-200506 discloses an arrangement in which a plurality of optical sheets, optical waveguide plate and another plurality of optical sheets, as well as an LCD panel, are fitted into a frame on the non-viewer side of the LCD panel (which will be referred to herein as the "lower side"). More specifically, in this arrangement, the inside portion of the frame, which is in contact with the lowermost sheet, is chamfered in an arc shape. This arrangement is designed so as to prevent the lens groove of the optical waveguide plate from being damaged. Thus, this publication discloses no arrangement for preventing the LCD panel from being damaged.

The problems of the prior art have been described with

LCDs taken as an example. However, those problems would happen not just in LCDs but also in any other display device in common if the display device includes a display panel that can be used as a flexible display (e.g., an organic EL display panel or an electrophoretic display panel).

DISCLOSURE OF INVENTION

In order to overcome the problems described above, a primary object of the present invention is to provide a display device of which the display panel is not damaged easily even when subjected to external force.

A display device according to the present invention includes a display panel with a substrate, and a frame including a supporting portion for supporting the display panel on the periphery thereof and on a principal surface of the substrate. The supporting portion includes a flat portion and a first curved portion, which are opposed to the principal surface of the substrate. The first curved portion is continuous with the flat portion. The principal surface of the substrate is fixed onto the flat portion either directly

or indirectly. While no external force is being applied to the substrate, a gap is left between the principal surface of the substrate and the first curved portion, whereby the object mentioned above is achieved.

In one preferred embodiment, the supporting portion includes a second curved portion that faces the first curved portion.

In another preferred embodiment, the principal surface of the substrate is fixed onto the flat portion with an adhesive layer.

In another preferred embodiment, the display device further includes a reinforcing plate between the principal surface of the substrate and the flat portion of the supporting portion.

In another preferred embodiment, the reinforcing plate is fixed onto the flat portion with an adhesive layer.

The supporting portion is preferably made of an elastic material.

The substrate is preferably a plastic substrate because the present invention is particularly effective then.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. **1(a)** to **1(c)** are cross-sectional views schematically illustrating an arrangement for a display device according to a preferred embodiment of the present invention.

FIGS. **2(a)** and **2(b)** are cross-sectional views schematically illustrating an arrangement for a display device according to another preferred embodiment of the present invention.

FIGS. **3(a)** and **3(b)** are cross-sectional views schematically illustrating an arrangement for a display device according to still another preferred embodiment of the present invention.

FIG. **4** is a cross-sectional view schematically illustrating an arrangement for a display device according to yet another preferred embodiment of the present invention.

FIGS. **5(a)** to **5(c)** are schematic cross-sectional views pointing out what problems may arise in a conventional mount structure for a display device.

FIG. **6** is a schematic cross-sectional view pointing out what problems may arise in a mount structure for a display

device of a comparative example.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, a structure for a display device according to a preferred embodiment of the present invention will be described with reference to the accompanying drawings. It should be noted that the present invention is in no way limited to the following preferred embodiments.

As shown in FIG. 1, a display device according to a preferred embodiment of the present invention includes a display panel **1** and a frame **2**, which is provided for the peripheral area (i.e., the area other than the display area) of the display panel. The display panel **1** includes one, two or more substrates, while the frame **2** includes a supporting portion **2** for supporting the display panel **1** on the peripheral area thereof and on the principal surface of the substrate. In FIG. 1, only the supporting portion **2** of the frame **2** is illustrated. Thus, the frame and the supporting portion are both identified by the same reference numeral "2", and the display panel and the substrate are both identified by the

same reference numeral "1". It should be noted that the supporting portion **2** and the frame **2** may either form integral parts of a single member or have been prepared separately and joined together.

The supporting portion **2** includes a flat portion **2a** and a first curved portion **2b**, which are provided so as to face the principal surface of the substrate **1**. The first curved portion **2b** is continuous with the flat portion **2a**. The principal surface of the substrate **1** is fixed onto the flat portion **2a** either directly or indirectly. In this preferred embodiment, the principal surface of the substrate **1** is fixed onto the flat portion **2a** with an adhesive layer **3** made of an adhesive.

While no external force is being applied to the display panel (or substrate) **1**, a gap is left between the principal surface of the substrate **1** and the curved portion **2b** as schematically shown in FIG. **1(a)**. This gap has been created so as to widen toward the (center of the) display area of the display panel **1**.

When external force is applied to the display panel **1** at

the center thereof, the display panel **1** deforms as schematically shown in FIG. **1(b)**. In this preferred embodiment, however, the supporting portion **2** has the curved portion **2b** beside the display area and the gap that widens toward the display area is provided between the supporting portion **2** and the principal surface of the substrate **1**. Thus, the display panel **1** can be deformed freely without being interfered with by the supporting portion **2**.

Also, even if the display panel **1** was deformed to such a degree as to be interfered with by the supporting portion **2**, no stress would be concentrated on the substrate **1** because it would be the curved portion **2b** that the substrate **1** would contact with as shown in FIG. **1(c)**.

As described above, the display device of this preferred embodiment of the present invention does not break easily even when external force is applied to the display panel (i.e., the substrate) thereof, and can be used effectively in a flexible display that uses a composite plastic substrate.

It should be noted that plastic substrates, including composite plastic substrates, usually absorb moisture. For

that reason, an inorganic film may be deposited on the surface of a plastic substrate and then circuit elements may be provided on the inorganic film. In that case, the inorganic film might be damaged before the substrate breaks. However, according to this preferred embodiment of the present invention, such inconveniences can also be eliminated.

The width of the flat portion **2a** of the supporting portion **2** is defined so as to secure the substrate **1** firmly. On the other hand, as long as the first curved portion **2b** has a curved surface opposed to the principal surface of the substrate **1**, the width of the curved portion **2b** (i.e., the width as projected on the principal surface of the substrate **1**) may be narrow. For example, if the display panel **1** has a size of 3 inches diagonally and if the substrate **1** has a thickness of 0.2 mm, then the flat portion **2a** may have a width of 3 mm to 5 mm. The present invention is particularly effective when the substrate **1** has a thickness of about 0.1 mm to about 0.5 mm.

The material of the supporting portion **2** is not particularly limited but is preferably a material with some

elasticity. This is because not only are the above effects achieved by providing the curved portion **2b** for the supporting portion **2** but also are the effects of cushioning the external force or shock through the deformation of the supporting portion **12** as shown in FIG. **5** achieved as well. The material with elasticity is preferably a rubber (elastomer) material such as a silicone or ether polyurethane rubber. The adhesive layer **3** is also preferably made of an adhesive with some elasticity (including a pressure sensitive adhesive). If the adhesive layer **3** with a thickness of about 20 μm is made of a pressure sensitive adhesive, then the pressure sensitive adhesive layer **3** is deformable easily enough to cause no stress on the substrate **1**.

However, if the adhesive layer **3** is made of a pressure sensitive adhesive, then the arrangement shown in FIG. **2** is preferably adopted.

Specifically, in the arrangement shown in FIGS. **2(a)** and **2(b)**, the adhesive layer **3** is provided only on the flat portion **2a** of the supporting portion **2**, not on the curved portion **2b** thereof. By adopting such an arrangement, even if

the display panel **1** has been deformed to such a degree as to contact with the curved portion **2b** as shown in FIG. **2(b)**, it is possible to prevent the display panel **1** from adhering and sticking to the adhesive layer **3** made of a pressure sensitive adhesive.

Optionally, alternative arrangements as shown in FIGS. **3(a)** and **3(b)** may also be adopted.

In the arrangement shown in FIG. **3(a)**, the supporting portion **2** includes not only the curved portion **2b** opposed to the principal surface of the substrate **1** but also another curved portion **2c** on the opposite side. By adopting such an arrangement, the end of the supporting portion **2** (i.e., that part with the curved portions **2b** and **2c**) is not fixed. Accordingly, even if the display panel **1** has been deformed to such a degree as to contact with the end of the supporting portion **2**, no stress will be produced on the display panel **1** because the end is easily deformable. To achieve these effects, the supporting portion **2** is preferably made of an elastic material.

In the arrangement shown in FIG. **3(b)** on the other hand,

in order to prevent the supporting portion **2** from interfering with the most significant deformation of the display panel **1** (i.e., to avoid placing any stress on the display panel **1**), the curved portion **2b** has an increased curvature (i.e., a decreased radius of curvature) and the pointed end of the supporting portion **2** is cut off. By adopting such an arrangement, the width of the inwardly (i.e., toward the display area) sticking part of the supporting portion **2** can be reduced. Consequently, the breakage of the display device can be minimized without increasing the overall size of the display device.

In the preferred embodiment described above, arrangements in which the display panel **1** is supported on the non-viewer-side principal surface of its substrate **1** have been taken as examples. As used herein, "to be supported on the principal surface of the substrate" does not always refers to an arrangement in which the principal surface of the substrate **1** is directly in contact with the supporting portion **2** of the frame but may broadly refer to any other arrangement in which the supporting portion **2** supports the display panel **1** by

applying force from the supporting portion 2 to the principal surface of the substrate 1 either directly or indirectly (i.e., by applying reaction to the gravity on the substrate 1). Accordingly, even if the display panel 1 is an LCD panel and if a polarizer and an optical film are provided on the outside surface of the lower plastic substrate of the LCD panel and adhered to the supporting portion 2 with the adhesive layer 3, the LCD panel 1 is also supported by the supporting portion 2 on the principal surface of its substrate.

Also, in the preferred embodiment described above, an arrangement in which the peripheral portion of the display panel 1 is fixed onto the frame on the non-viewer-side principal surface of the substrate has been exemplified. However, similar effects are also achievable even if the display panel is fixed onto the frame on the viewer-side principal surface of the substrate or on both principal surfaces (i.e., on the outside principal surface of a single substrate or on the outside principal surfaces of two substrates).

Furthermore, in the preferred embodiment described above, an arrangement in which the display panel **1** is fixed onto the frame **2** with the adhesive layer **3** is adopted. However, the display panel **1** does not have to be fixed onto the frame **2** in this way. For example, a transparent plate (preferably with an opening corresponding in shape to the display area) may be put on the upper surface (i.e., the viewer-side surface) of the display panel **1** such that the display panel is sandwiched between this plate and the frame and that these members are screwed up.

Alternatively, a reinforcing plate of a plastic or a metal, of which the size is equal to or greater than that of the display panel 1, may be provided between the display panel **1** and the supporting portion **2** as shown in FIG. **4**. The reinforcing plate **4** is fixed on the flat portion **2a** of the supporting portion **2** either directly or indirectly. While no external force is being applied to the display panel 1, a gap is left between the reinforcing plate **4** and the curved portion **2b** of the supporting portion 2. The display panel **1** may be secured to the reinforcing plate **4** with an adhesive layer 3,

which is provided outside of the display area. It should be noted that the reinforcing plate **4** could be provided on the viewer side, the non-viewer side or even both sides of the display panel **1**.

The reinforcing plate **4** preferably has rigidity that is equal to or greater than that of the substrate **1** of the display panel. To prevent the flexibility required for the display device from being affected by the presence of the reinforcing plate **4**, the thickness of the reinforcing plate **4** is preferably adjusted according to the Young's modulus of the material of the reinforcing plate **4**. In a mobile application, the reinforcing plate **4** preferably has a thickness of 0.1 mm to 0.5 mm, for example, considering the thickness and the lightness of the display device.

By adopting such an arrangement, even if the reinforcing plate **4** were deformed, no stress would be concentrated on the contact region between the reinforcing plate **4** and the supporting portion **2** and the breakage of the reinforcing plate **4** can be minimized, unlike the arrangement shown in FIG. **6** that uses the supporting portion **22** with a pointed corner.

Once the reinforcing plate **4** has broken, significant stress would be concentrated on the display panel **1** at the breaking point to possibly damage the display panel (or substrate) **1**. If the reinforcing plate **4** is soft, then such breakage is less likely to occur but the plate **4** cannot reinforce the substrate **1** so effectively. Nevertheless, if the reinforcing plate has high rigidity, then a flexible display cannot be fabricated. Thus, when the arrangement shown in FIG. **6** is adopted, it is difficult to select appropriate material (i.e., degree of rigidity) and thickness for the reinforcing plate **4**.

In contrast, if the curved portion **2b** is provided at the edge of the supporting portion **4** as shown in FIG. **4**, then no stress will be concentrated on the reinforcing plate **4**. Consequently, the reinforcing plate **4** may be made of a material selected from a wider variety of options and can function fully effectively.

In FIG. **4**, the display panel **1** is secured to the reinforcing plate **4** with the adhesive layer **3**. Alternatively, a different arrangement using no adhesive layer **3** may also be

adopted. The same statement applies to the method of securing the reinforcing plate **4** to the supporting portion **2**. That is to say, the reinforcing plate **4** may be fixed either with an adhesive layer or by any other technique (e.g., screwed up as described above).

Also, in the arrangement illustrated in FIG. **4**, the edge of the display panel **1** overlaps with the flat portion **2a** of the supporting portion **2**. However, even if the edge of the display panel **1** does not overlap with the flat portion **2a**, similar effects are also achieved as long as the reinforcing plate **4** is secured to the flat portion **2a** of the supporting portion **2**.

The present invention is particularly effectively applicable to a display device with a composite plastic substrate, which is characterized by being deformable more greatly than a conventional glass substrate. However, even when the present invention is applied to a display device with a glass substrate, the breakage can be minimized, too.

INDUSTRIAL APPLICABILITY

As described above, the present invention provides a display device, of which the display panel is not damaged easily even when subjected to external force. The present invention is effectively applicable for use in a flexible display, which uses a composite plastic substrate that is characterized by being deformable more greatly than a conventional glass substrate.